

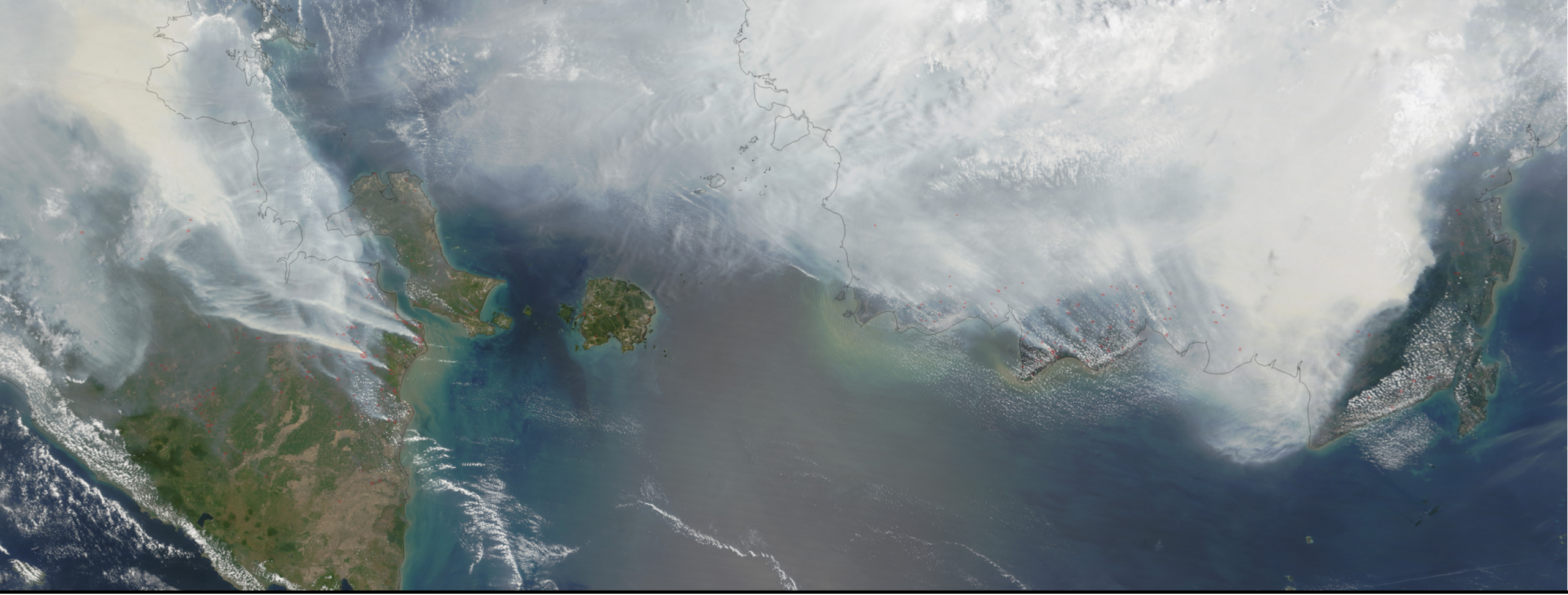
# Converting AOD to $PM_{2.5}$ : a Statistical Approach

Pawan Gupta, Melanie Follette-Cook, and Bryan Duncan

NASA Remote Sensing for Air Quality Applications, March 20-23, 2018, Jakarta, Indonesia

# Objective

- By the end of this exercise, you will be able to
  - convert satellite derived aerosol optical depth into surface level PM<sub>2.5</sub> mass concentration using a statistical approach

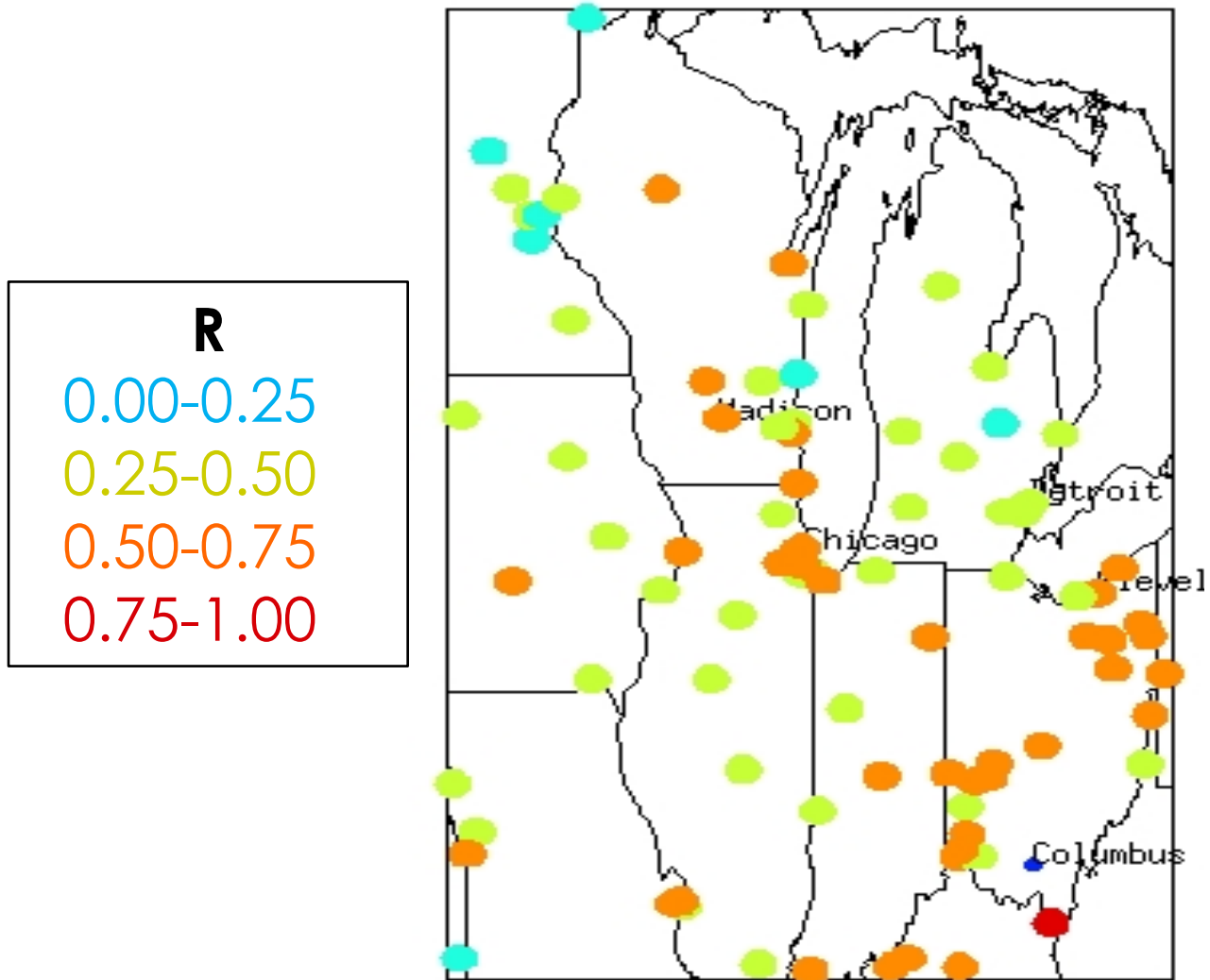


# Exercise 1: Converting AOD to $PM_{2.5}$

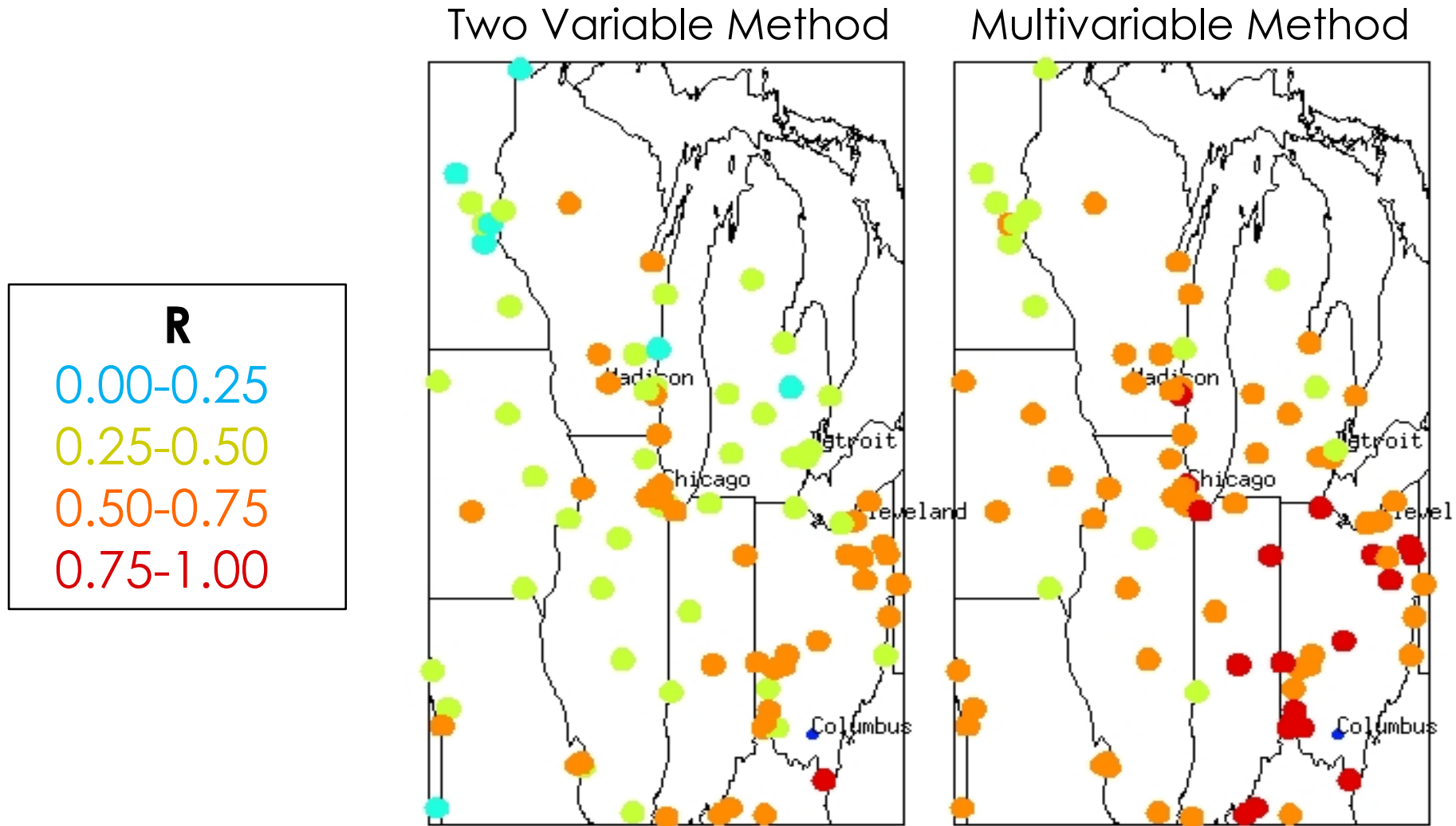
# Required Data

- $PM_{2.5}$  mass concentration from ground monitors
- Satellite-derived aerosol optical depth
- Meteorological fields (only if working with a multi-variable method)

# Correlation Between PM<sub>2.5</sub> and AOD



# Correlation Between PM<sub>2.5</sub> and AOD



# Converting AOD to PM<sub>2.5</sub> to AQC

## Step 1: Getting Satellite and Surface Data

- Obtain MODIS AOD data file from a NASA data server for your region, date, and time of interest
  - <https://ladsweb.modaps.eosdis.nasa.gov/>
  - from earlier exercise
- To get PM<sub>2.5</sub> for your region:
  - For U.S. Data: [http://www.epa.gov/airdata/ad\\_maps.html](http://www.epa.gov/airdata/ad_maps.html)
  - Global Air Quality Monitoring System: <http://aqicn.org>
  - Global open data: <http://openaq.org>
  - Your own data source or measurements

# Converting AOD to PM<sub>2.5</sub> to AQC

## Step 2: Collocating Satellite and Surface Data

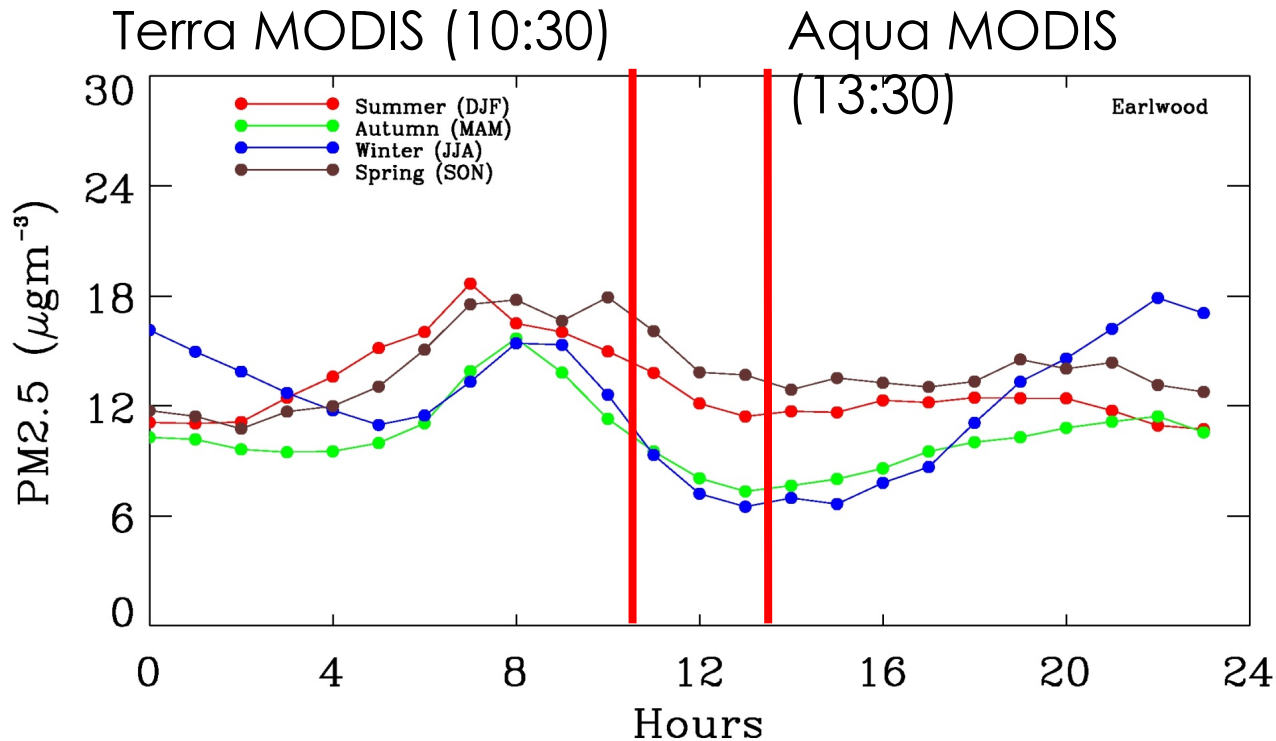
- Run IDL, Matlab, HDFLook, Python, etc. code to obtain AOD at the location of the PM<sub>2.5</sub> ground monitor
  - Python scripts: <https://arset.gsfc.nasa.gov/airquality/python-scripts-aerosol-data-sets-merra-modis-and-omi>
  - IDL code:  
[http://arset.gsfc.nasa.gov/sites/default/files/airquality/workshops/Santa\\_Cruz\\_2013/read\\_mod04\\_map\\_aqc.zip](http://arset.gsfc.nasa.gov/sites/default/files/airquality/workshops/Santa_Cruz_2013/read_mod04_map_aqc.zip)



# Converting AOD to PM<sub>2.5</sub> to AQC

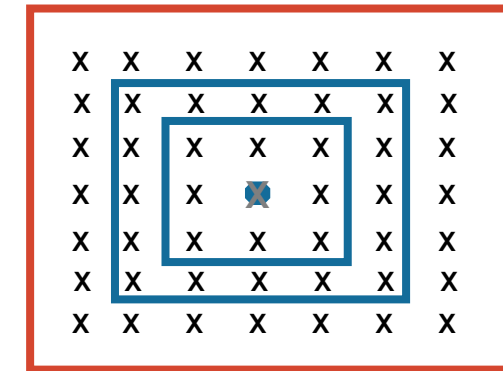
## Step 2: Collocating Satellite and Surface Data

### Temporal Collocation



pick the closest PM<sub>2.5</sub> measurement from ground to satellite overpass time

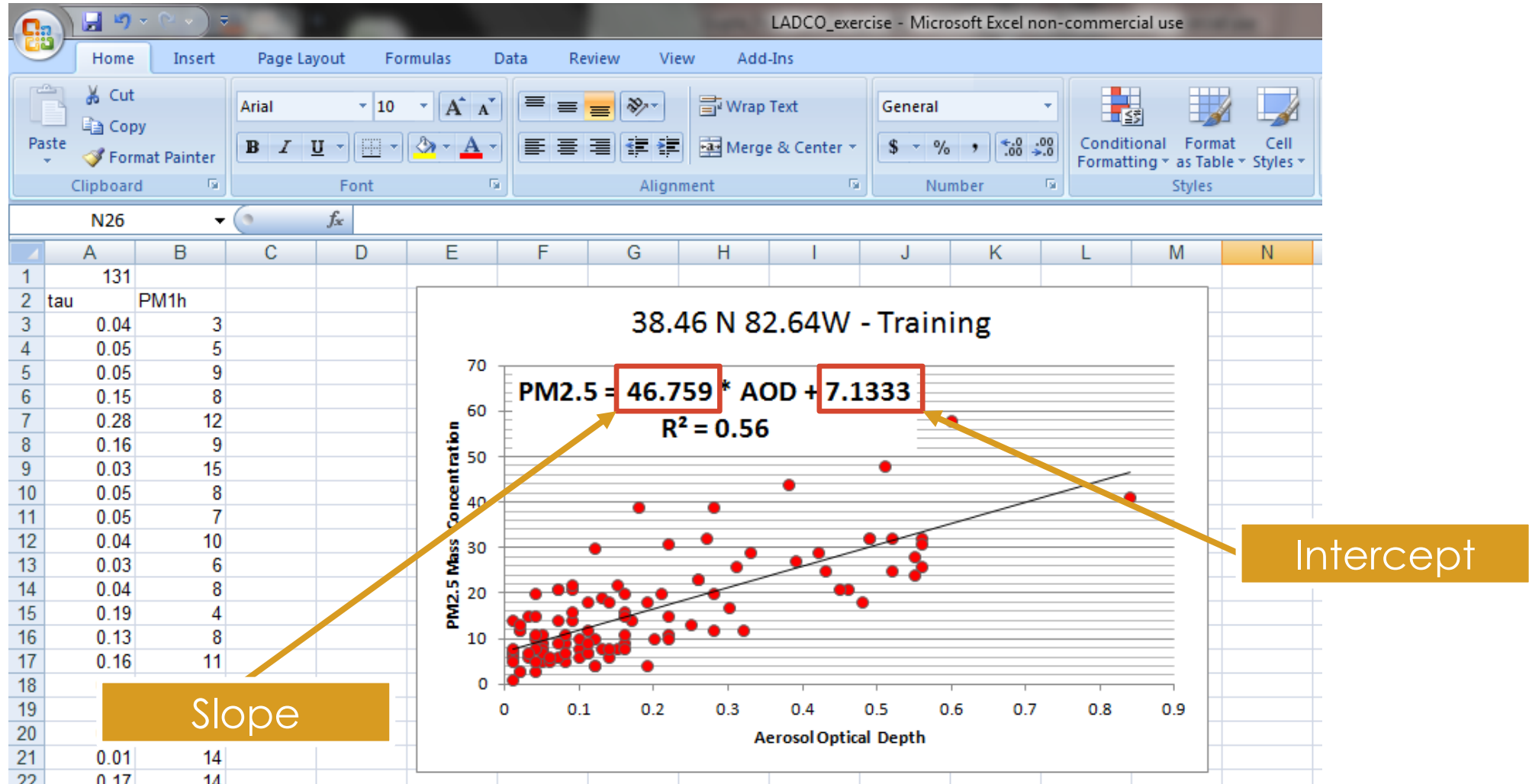
### Spatial Collocation



pick the nearest pixel or average over 3x3 or 5x5 pixels

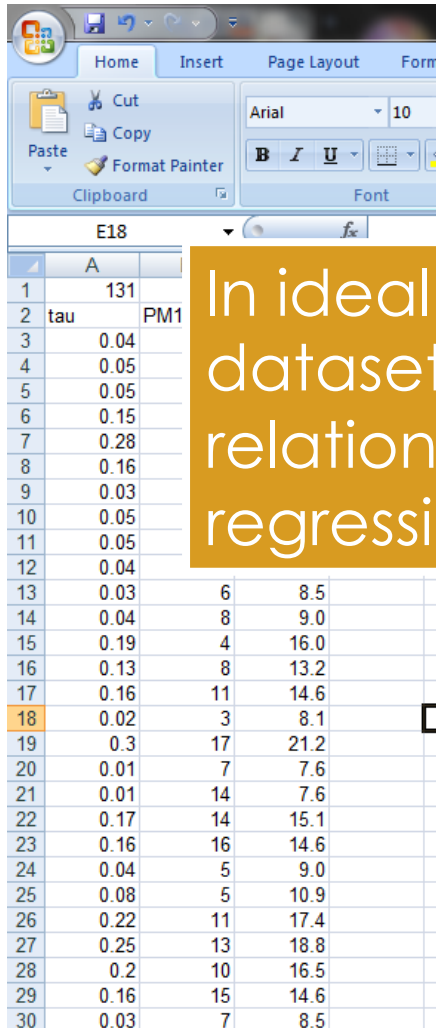
# Converting AOD to PM<sub>2.5</sub> to AQC

## Step 3: Developing a Relationship Between AOD & PM<sub>2.5</sub>



# Converting AOD to PM<sub>2.5</sub> to AQC

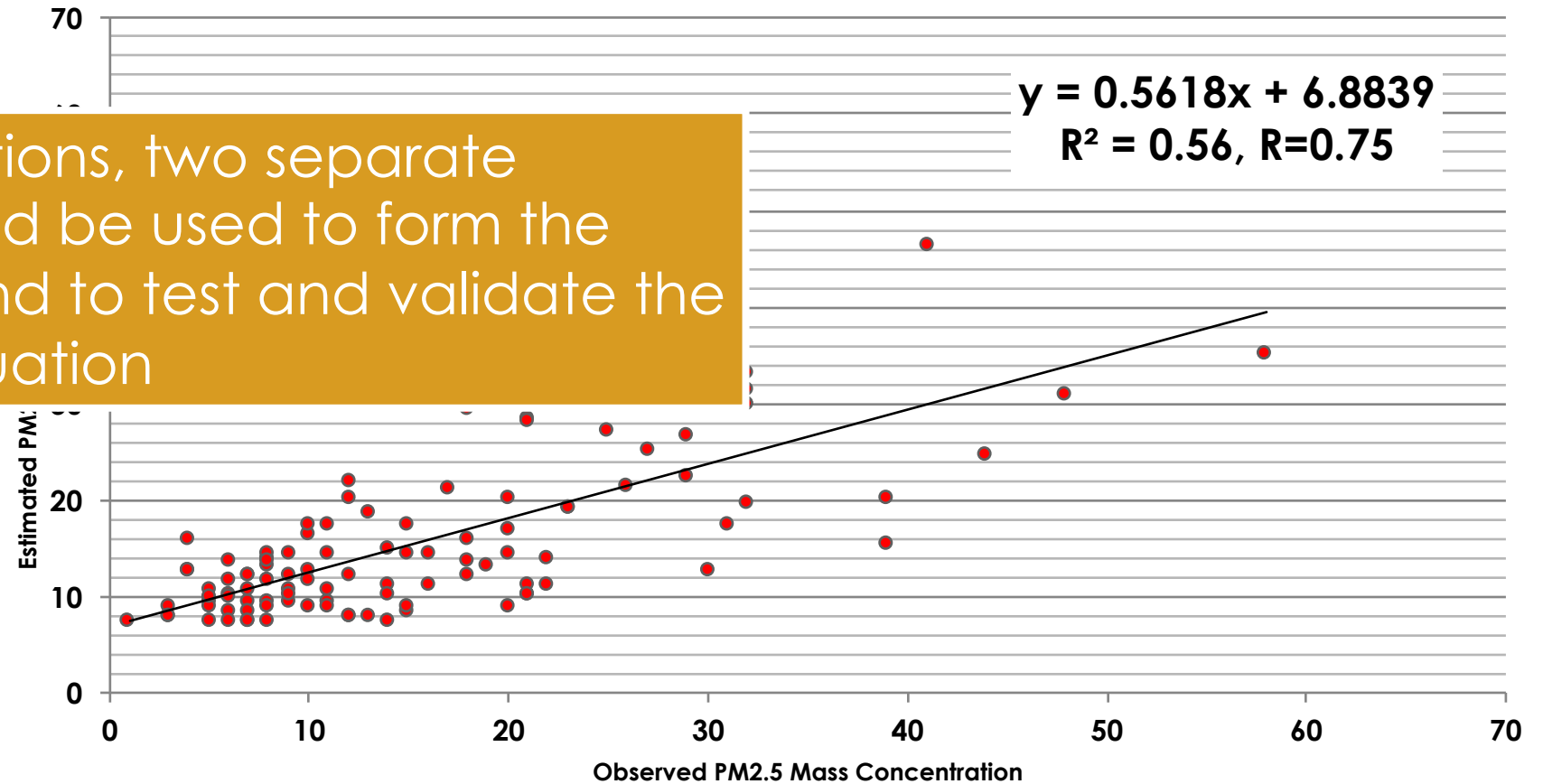
## Step 4: Estimating PM<sub>2.5</sub> from Satellite AOD



	A	B	C
1	131		
2	tau	PM1	
3	0.04		
4	0.05		
5	0.05		
6	0.15		
7	0.28		
8	0.16		
9	0.03		
10	0.05		
11	0.05		
12	0.04		
13	0.03	6	8.5
14	0.04	8	9.0
15	0.19	4	16.0
16	0.13	8	13.2
17	0.16	11	14.6
18	0.02	3	8.1
19	0.3	17	21.2
20	0.01	7	7.6
21	0.01	14	7.6
22	0.17	14	15.1
23	0.16	16	14.6
24	0.04	5	9.0
25	0.08	5	10.9
26	0.22	11	17.4
27	0.25	13	18.8
28	0.2	10	16.5
29	0.16	15	14.6
30	0.03	7	8.5

$$\text{PM}_{2.5} = \text{AOD} * 46.7 + 7.13$$

In ideal conditions, two separate datasets should be used to form the relationship and to test and validate the regression equation



# Converting AOD to PM<sub>2.5</sub> to AQC

## Step 5: PM<sub>2.5</sub> to Air Quality

Category	AQI Estimated 24-hour avg. µg/m <sup>3</sup>
Good (0 - 50)	0 to 15.4
Moderate (51 - 100)	15.5 to 40.4
Unhealthy for Sensitive Groups (101 - 150)	40.5 to 65.4
Unhealthy (151 - 200)	65.5 to 150.4
Very Unhealthy (201 - 300)	150.5 to 250.4
Hazardous (301 - 500)	>250.4

## Online Tool

### AQI Calculator: Concentration to AQI



Select a criteria pollutant and enter the pollutant concentration in the specified units above; the Air Quality Index and associated information are calculated below.

Select a Pollutant

PM2.5 - Particulate <2.5 microns (24hr avg) ▼

Units Required: ug/m3

Enter the Concentration: 15.5

AQI

51

AQI Category

Moderate

Sensitive Groups

People with respiratory or heart disease, the elderly and children are the groups most at risk.

Health Effects Statements

None

Cautionary Statements

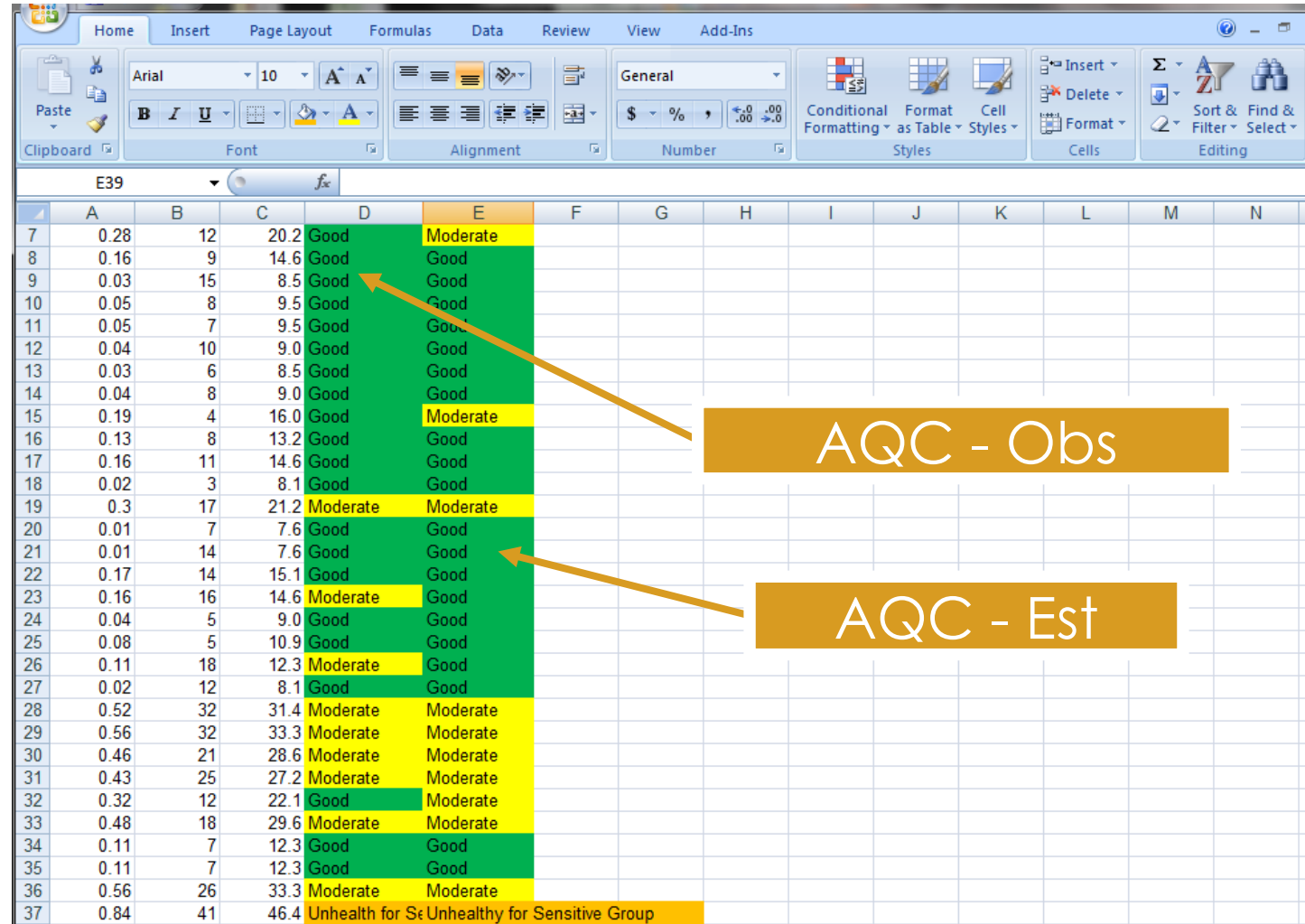
None

This is based on the U.S. EPA's definition of AQI, which can be different in other countries



# Converting AOD to PM<sub>2.5</sub> to AQC

## Step 5: PM<sub>2.5</sub> to Air Quality



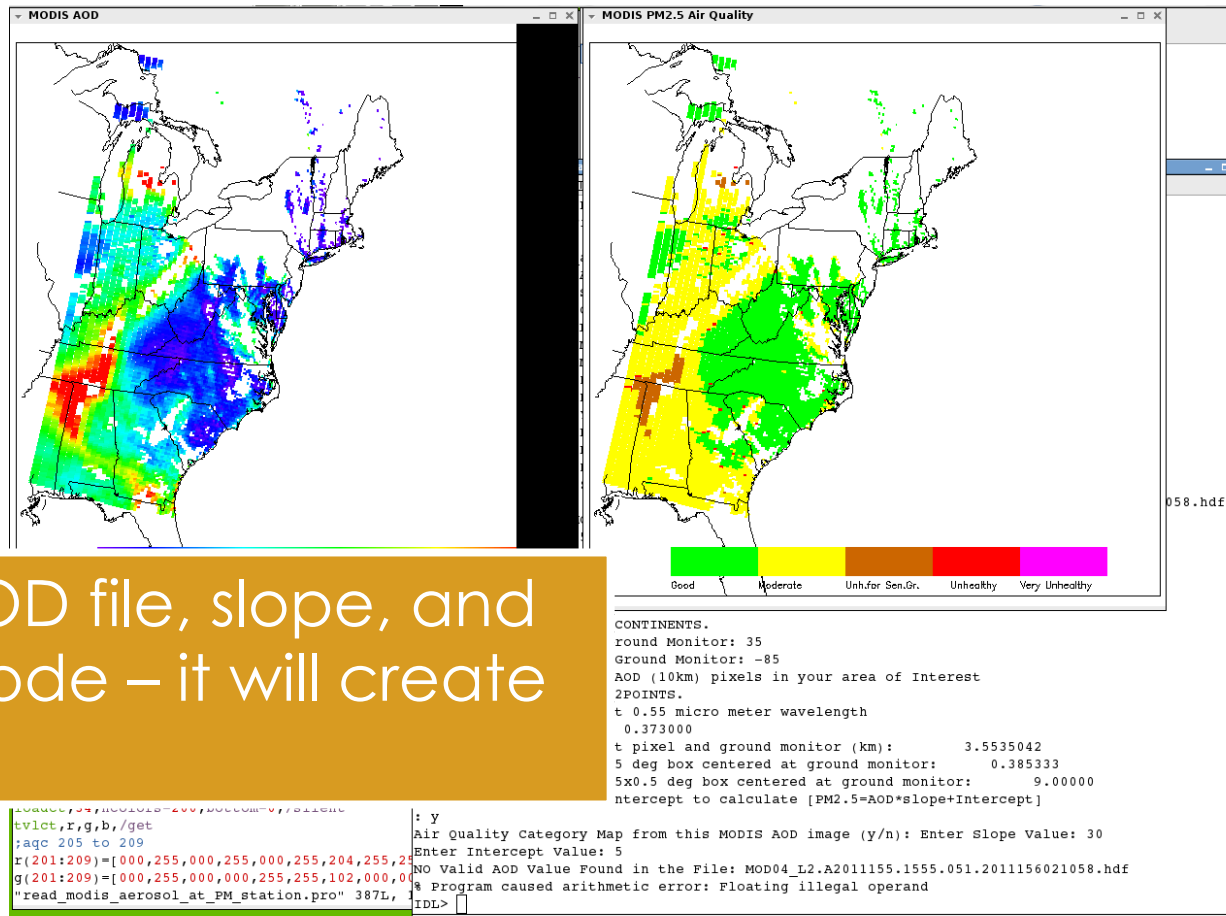
	A	B	C	D	E
7	0.28	12	20.2	Good	Moderate
8	0.16	9	14.6	Good	Good
9	0.03	15	8.5	Good	Good
10	0.05	8	9.5	Good	Good
11	0.05	7	9.5	Good	Good
12	0.04	10	9.0	Good	Good
13	0.03	6	8.5	Good	Good
14	0.04	8	9.0	Good	Good
15	0.19	4	16.0	Good	Moderate
16	0.13	8	13.2	Good	Good
17	0.16	11	14.6	Good	Good
18	0.02	3	8.1	Good	Good
19	0.3	17	21.2	Moderate	Moderate
20	0.01	7	7.6	Good	Good
21	0.01	14	7.6	Good	Good
22	0.17	14	15.1	Good	Good
23	0.16	16	14.6	Moderate	Good
24	0.04	5	9.0	Good	Good
25	0.08	5	10.9	Good	Good
26	0.11	18	12.3	Moderate	Good
27	0.02	12	8.1	Good	Good
28	0.52	32	31.4	Moderate	Moderate
29	0.56	32	33.3	Moderate	Moderate
30	0.46	21	28.6	Moderate	Moderate
31	0.43	25	27.2	Moderate	Moderate
32	0.32	12	22.1	Good	Moderate
33	0.48	18	29.6	Moderate	Moderate
34	0.11	7	12.3	Good	Good
35	0.11	7	12.3	Good	Good
36	0.56	26	33.3	Moderate	Moderate
37	0.84	41	46.4	Unhealthy for Sensitive Group	Unhealthy for Sensitive Group



# Creating an Air Quality Category Map

## Python/IDL Tool

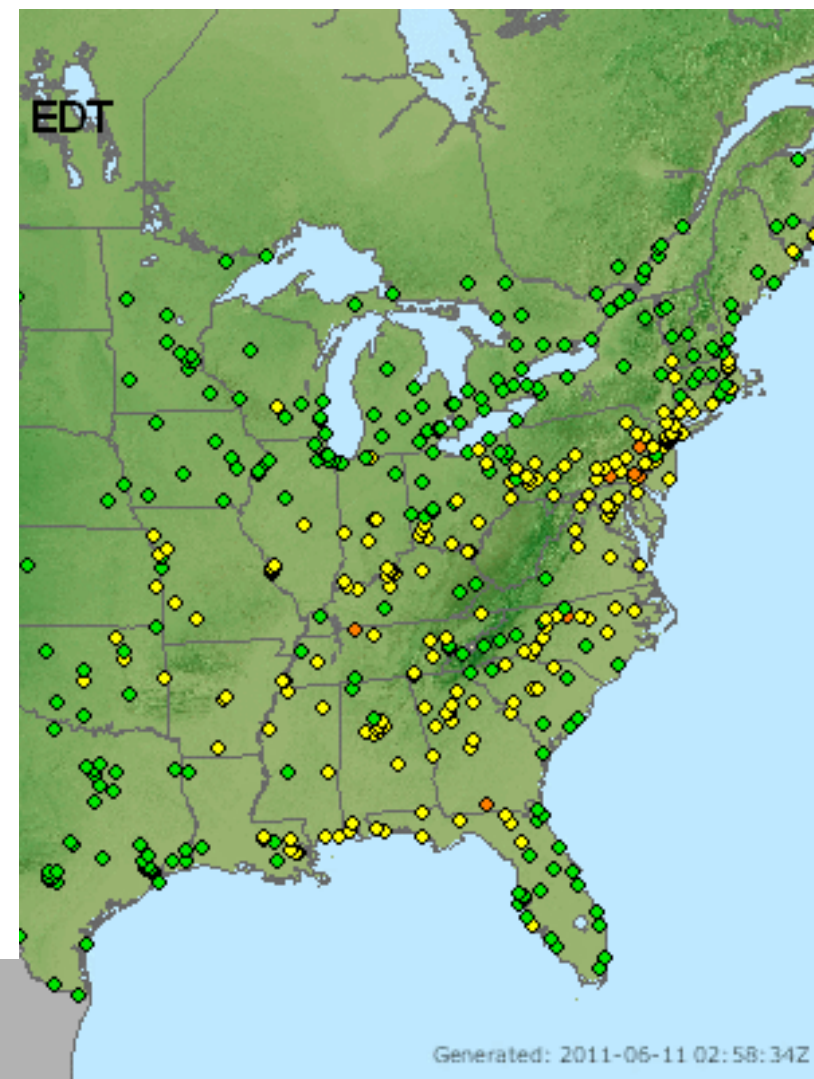
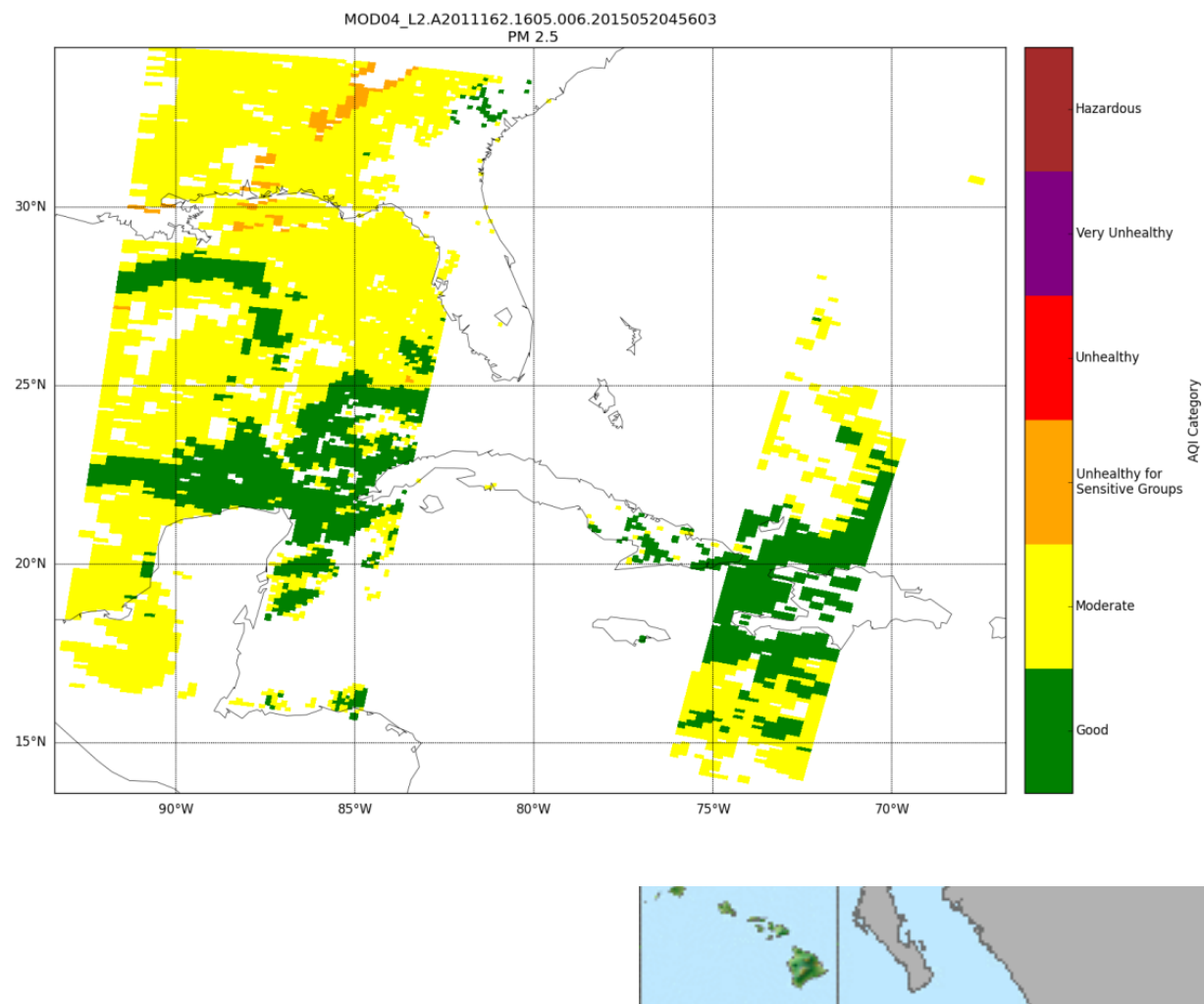
<http://arset.gsfc.nasa.gov/airquality/python-scripts-aerosol-data-sets-merra-modis-and-omi>



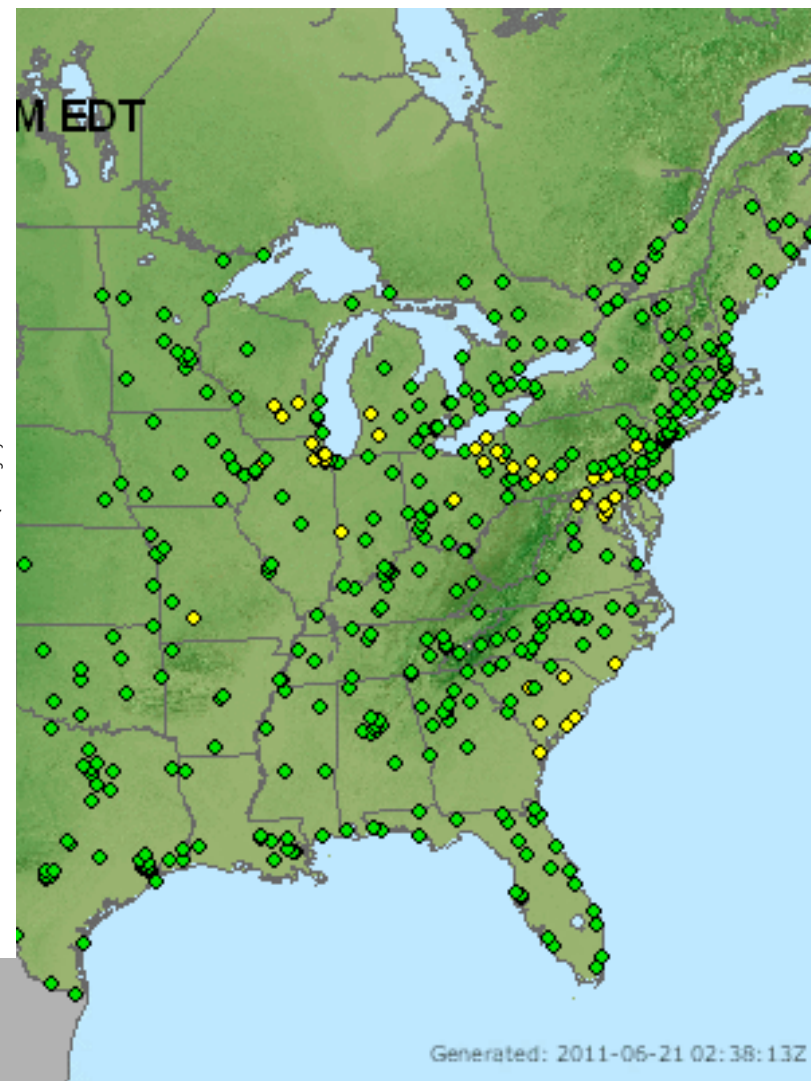
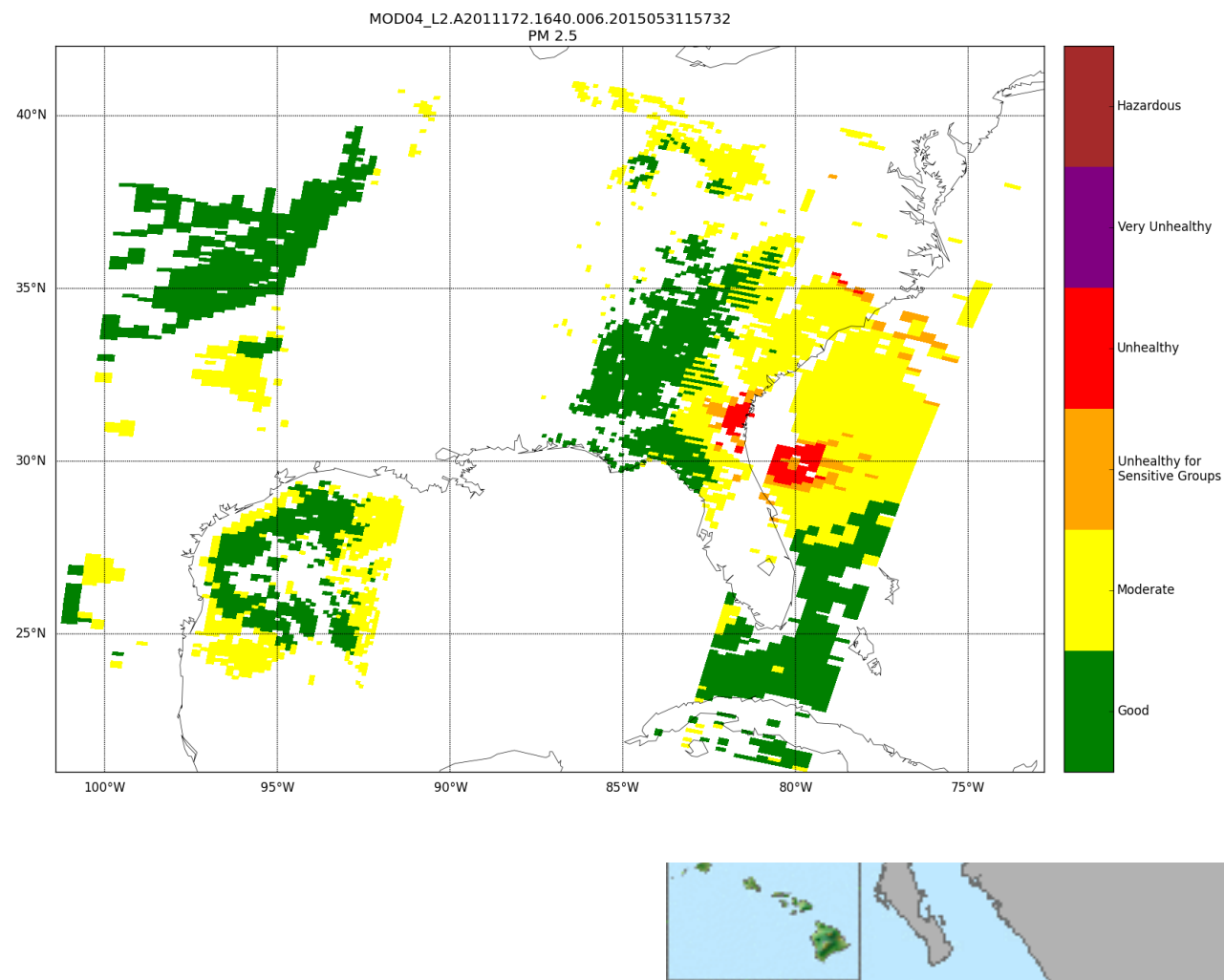
Provide MODIS AOD file, slope, and intercept to this code – it will create AQC map



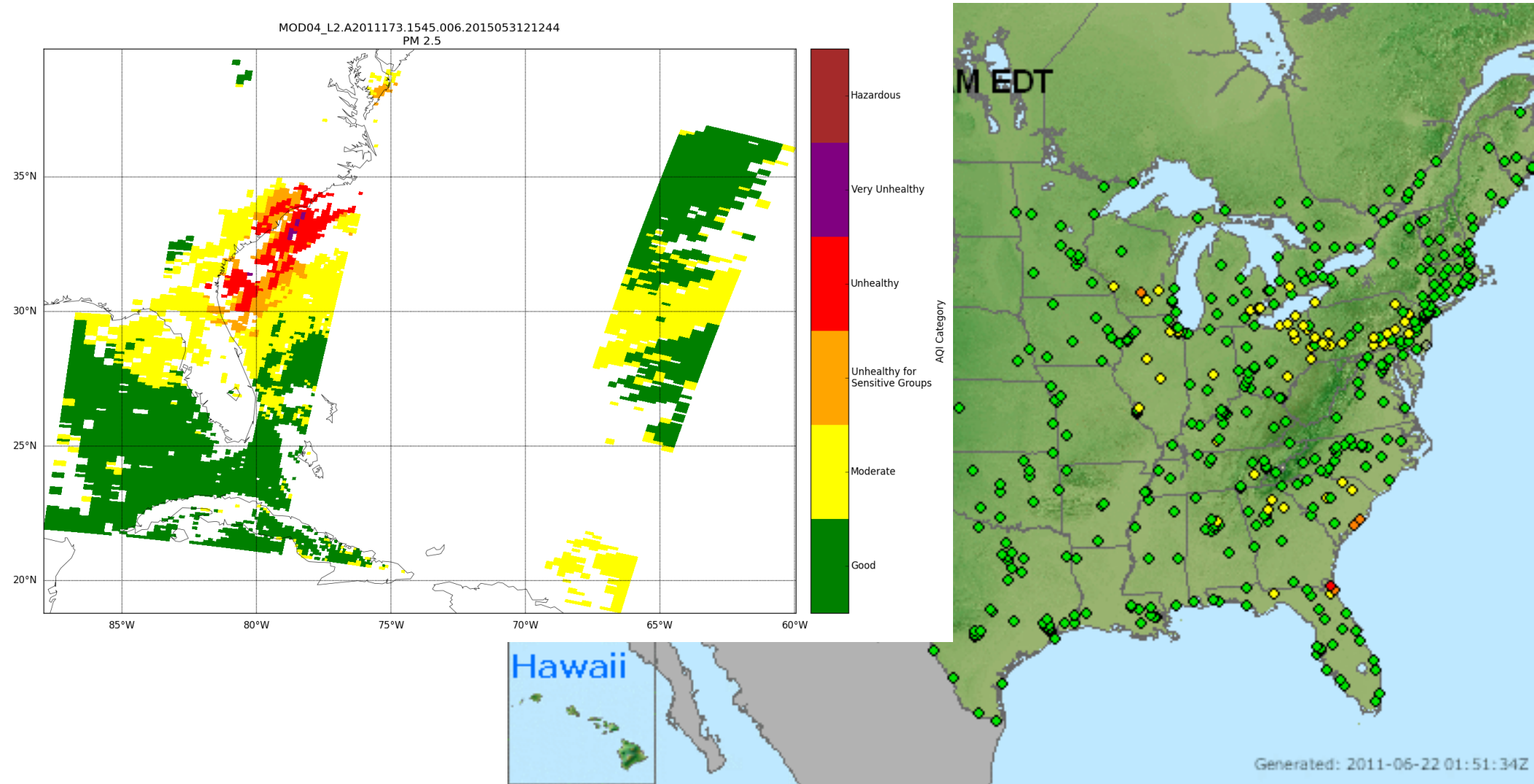
June 10, 2011



June 10, 2011



June 21, 2011



# Multiple Linear Regression Method

$$PM_{2.5} = \beta_0 + \alpha \times \tau + \sum (\beta_n \times M_n)$$

- This method requires AOD, meteorological fields, more data processing, and more expertise
- Most of the time this produced a more accurate  $PM_{2.5}$  estimation



# Multiple Linear Regression Models

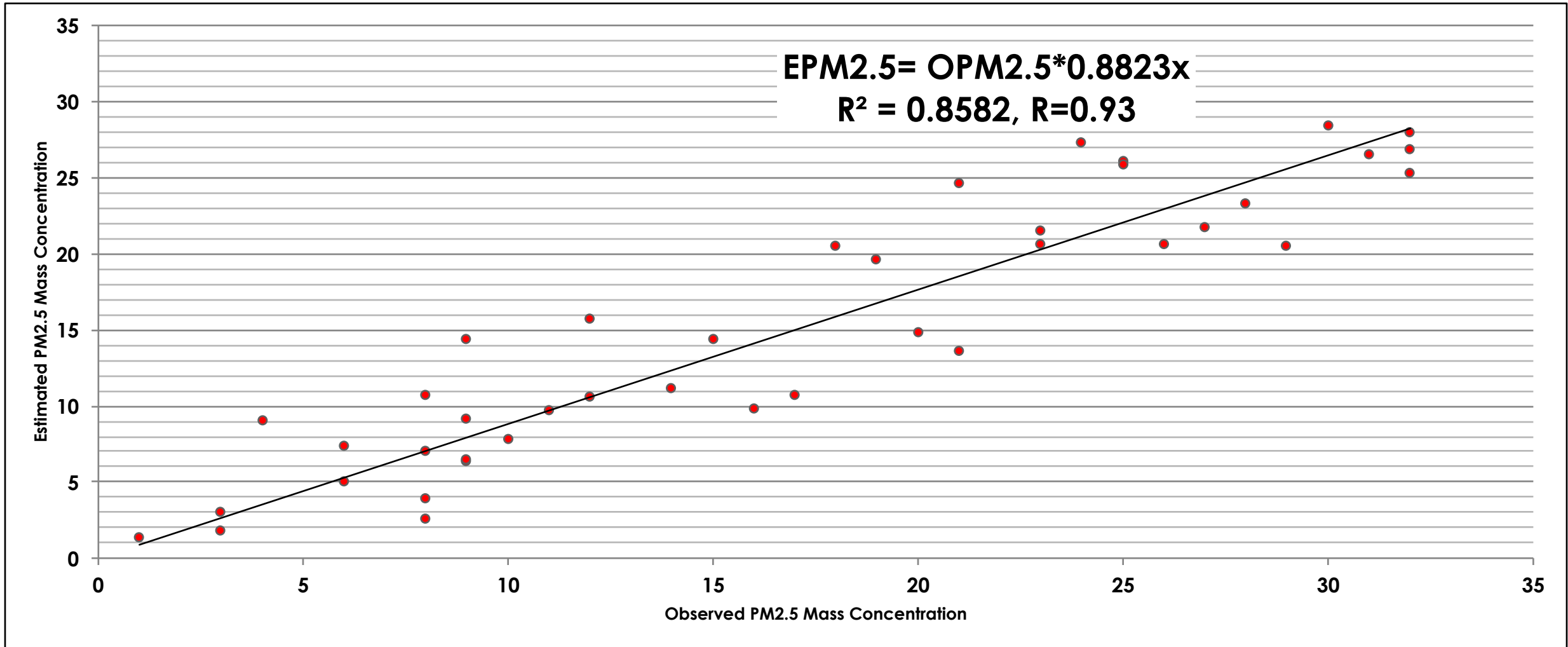
## AOD, PM<sub>2.5</sub>, and Meteorological Data

N3													=17.02*A3+1.14*D3-0.92*E3+0.44*F3-0.95*G3+1.04*H3-0.04*I3-0.31*J3-0.031*K3-0.0022*L3-177.26	
	C	D	E	F	G	H	I	J	K	L	M	N	O	
1	Latitude = 38.46, Longitude = -82.64													
2	PM1h	tmp0	tmp1000	tmp700	rh0	rh1000	rh700	ws0	ws925	hpbl		EPM2.5		
3	3	277.47	277.4	266.05	71.26	71	70.32	4.14	16.22	63.33		2.995254	3	
4	9	287.25	285.97	270.8	28.95	29.41	39.34	2.76	1.41	623.5		6.35489		
5	8	274.13	273.1	260.93	63.01	63.56	17.28	4	8.79	675.67		3.911136		
6	12	287.43	286.53	269.72	46.23	46.52	23.82	3.64	9.04	800.67		10.58439	3	
7	9	275.9	275.85	264.3	59.98	60.34	11.2	3.39	5.76	53		6.47774		
8	8	283.18	281.67	265.93	35.44	35.57	79.54	0.65	2.47	676.83		2.494904		
9	3	286.07	283.98	265.25	36.55	36.66	42.77	4.46	9.49	1325.83		1.748084	2	
10	17	297.03	297.98	275.33	52.06	51.57	81.85	4.04	13.09	925.5		10.67131		
11	14	296.88	294.37	274.78	29.43	29.35	27.39	2.18	6.37	1633.33		11.1627		
12	16	297.05	295.72	275.03	25.06	25.43	44.91	4.98	16.45	914.83		9.828424	2	
13	15	299.85	297.52	275.25	42.4	42.92	42.66	3.17	6.19	1281.5		14.36151		
14	6	289.07	287.65	269.45	57.64	58.14	68.48	4.43	34.55	478.83		7.372424	1	
15	10	295.3	293.57	273.68	42.91	43.34	88.06	3.94	17.43	1226		7.74657		
16	32	301.9	299.88	282.63	51.67	51.79	32.02	2.83	9.8	585.17		25.24983		
17	32	303.42	300.45	282.27	50.19	50.36	23.46	2.64	6.74	833.5		26.84926		
18	21	299.68	297.82	279.97	80.46	80.25	68.37	2.38	6.51	75		24.58039	1	
19	25	304.13	301.87	283.48	64.15	64.42	31.91	3.5	6.1	541.17		26.09083		
20	12	295.48	295.2	276.62	64.84	63.68	18.02	4.36	6.28	849.83		15.65489		
21	18	300.6	297.15	276.12	45.32	45.23	21.52	1.03	2.05	1799.67		20.49068		
22	29	302.4	299.1	279.78	60.49	60.86	47.22	3.41	5.88	1457.67		20.51765		
23	23	303.7	300.62	282.55	60.82	60.86	12.18	2.56	6.53	1655.67		21.5245		
24	32	307.48	303.73	284.97	63.16	63.1	57.85	1.99	6.4	969.83		27.92127		
25	23	306.27	304.75	282.85	59.03	58.51	43.11	2.42	6.73	880.5		20.54857		
26	19	307.38	304.78	283.63	51.07	51.09	34.56	4.67	7.7	777.83		19.60247		
27	25	306.15	303.15	283.25	60.33	60.41	56.95	4.62	6.13	953.83		25.84764		
28	28	304.92	303.35	283.4	63.96	63.78	81.48	2.4	6.46	1561.83		23.25351		
29	30	302.98	302.9	281.58	59.39	59.84	94.25	3.08	6.66	1391.33		28.37551		
30	31	301.35	300.05	282.43	60.76	60.4	33.71	2.94	7.29	89.33		26.44508		
31	24	305.43	302.2	280.67	55.96	56.51	23.92	2.29	3.24	1058.83		27.27383		
32	27	301.4	300.42	281.02	56.77	57.2	22.22	4.04	10.04	537.6		21.71764		

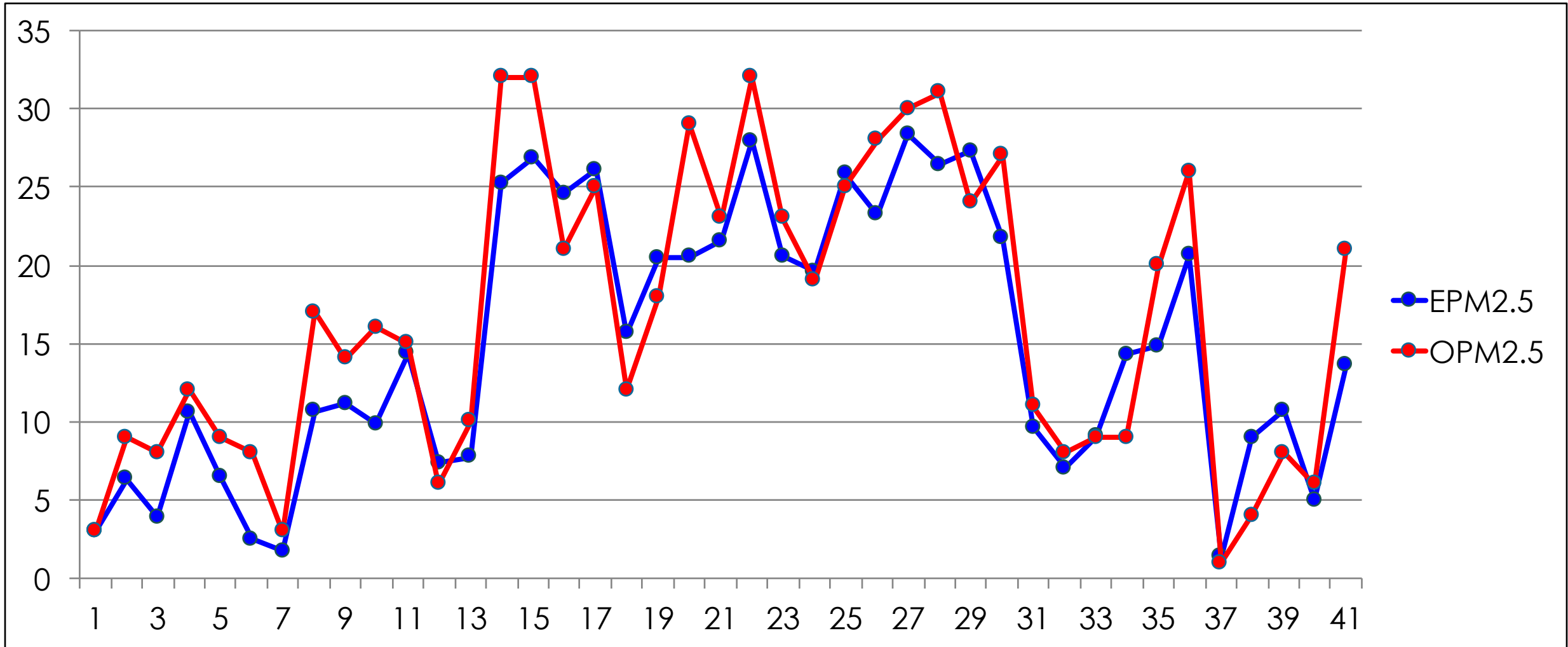
Estimated PM2.5 Mass Concentration



# Multiple Linear Regression Method Results



# Multiple Linear Regression Method Results



## !! CAUTION !!

- Regression analysis provides the first approximation of surface PM<sub>2.5</sub> mass concentration and air quality
- Its accuracy depends on training data and varies in space and time
- Careful data quality control, testing, and validation should be performed before using this method for quantitative analysis
- Works best when the boundary layer is well mixed, there is no significant aerosol aloft, and in small particle dominated regions



# Existing Data Satellite Based Sets for CONUS

- IDEA
  - <https://www.star.nesdis.noaa.gov/smcd/spb/aq/>
- e-IDEA
  - <https://www.star.nesdis.noaa.gov/smcd/spb/aq/eidea/>
- ASDP
  - <https://asdp.airnowtech.org/about.php>
- Dalhousie
  - [http://fizz.phys.dal.ca/~atmos/martin/?page\\_id=140](http://fizz.phys.dal.ca/~atmos/martin/?page_id=140)
- Smog Blog
  - <http://alg.umbc.edu/usaq/>

